

**WHAT IS CLAIMED IS:**

**CLAIMS**

1. An integrated circuit comprising:  
a summer operative to receive an input signal having a transmit leakage signal and to receive an estimator signal having an estimate of the transmit leakage signal, to subtract the estimator signal from the input signal, and to provide an output signal having the transmit leakage signal attenuated, wherein the transmit leakage signal corresponds to a portion of a modulated signal being transmitted in a wireless full-duplex communication system; and  
an estimator operative to receive the output signal and a reference signal having a version of the modulated signal, to estimate the transmit leakage signal in the input signal based on the output signal and the reference signal, and to provide the estimator signal having the estimate of the transmit leakage signal.
2. The integrated circuit of claim 1, further comprising:  
a low noise amplifier (LNA) operative to amplify a receiver input signal and provide the input signal.
3. The integrated circuit of claim 1, further comprising:  
a low noise amplifier (LNA) operative to amplify the output signal and provide an amplified signal for frequency downconversion to baseband.
4. The integrated circuit of claim 1, further comprising:  
a mixer operative to frequency downconvert the output signal with a local oscillator (LO) signal and provide a downconverted signal.
5. The integrated circuit of claim 1, wherein the estimator utilizes a least mean squared (LMS) algorithm to minimize a mean square error (MSE) between the transmit leakage signal in the input signal and the estimate of the transmit leakage signal in the estimator signal.
6. The integrated circuit of claim 1, wherein the estimator comprises

a first multiplier operative to multiply the output signal with an in-phase reference signal and to provide a first in-phase signal,

a first integrator operative to integrate the first in-phase signal and to provide a second in-phase signal,

a second multiplier operative to multiply the second in-phase signal with the in-phase reference signal or a quadrature reference signal and to provide a third in-phase signal, wherein the in-phase and quadrature reference signals are generated from the reference signal,

a third multiplier operative to multiply the output signal with the quadrature reference signal and to provide a first quadrature signal,

a second integrator operative to integrate the first quadrature signal and to provide a second quadrature signal, and

a fourth multiplier operative to multiply the second quadrature signal with the in-phase or quadrature reference signal and to provide a third quadrature signal, and wherein the estimator signal is obtained by summing the third in-phase signal and the third quadrature signal.

7. The integrated circuit of claim 6, further comprising:

a quadrature splitter operative to receive the reference signal and provide the in-phase reference signal and the quadrature reference signal.

8. The integrated circuit of claim 6, wherein the second multiplier is operative to multiply the second in-phase signal with the quadrature reference signal, and wherein the fourth multiplier is operative to multiply the second quadrature signal with the in-phase reference signal.

9. The integrated circuit of claim 6, wherein the second multiplier is operative to multiply the second in-phase signal with the inphase reference signal, and wherein the fourth multiplier is operative to multiply the second quadrature signal with the quadrature reference signal.

10. The integrated circuit of claim 6, wherein the first, second, third, and fourth multipliers are implemented with mixers, and wherein the in-phase and quadrature reference signals are used as local oscillator (LO) signals for the mixers.

11. The integrated circuit of claim 6, wherein the estimator further comprises a first lowpass filter coupled between the first integrator and the second multiplier, and

a second lowpass filter coupled between the second integrator and the fourth multiplier.

12. The integrated circuit of claim 11, wherein the first and second lowpass filters are single-pole lowpass filters.

13. The integrated circuit of claim 6, further comprising:  
switches operable to reset outputs of the first and second integrators prior to enabling the estimator.

14. The integrated circuit of claim 6, wherein the first through fourth multipliers and the first and second integrators are implemented with a differential circuit design.

15. The integrated circuit of claim 1, wherein the estimator is operable to derive a set of weight values based on a training burst, and to use the set of weight values to estimate the transmit leakage signal in the input signal.

16. The integrated circuit of claim 1, wherein the estimator provides at least 30 dB of rejection of the transmit leakage signal.

17. A wireless device in a wireless full-duplex communication system, comprising:

a low noise amplifier (LNA) operative to amplify a receiver input signal and to provide an input signal having a transmit leakage signal, wherein the transmit leakage signal corresponds to a portion of a modulated signal being transmitted;

an adaptive filter operative to receive the input signal and a reference signal having a version of the modulated signal, to generate an estimator signal having an estimate of the transmit leakage signal based on an output signal and the reference signal, and to subtract the estimator signal from the input signal to obtain the output signal having the transmit leakage signal attenuated; and

a mixer operative to receive and frequency downconvert the output signal with a local oscillator (LO) signal and to provide a downconverted signal.

18. The wireless device of claim 17, wherein the wireless full-duplex communication system is a Code Division Multiple Access (CDMA) system.

19. The wireless device of claim 17, wherein the adaptive filter utilizes a least mean squared (LMS) algorithm to minimize a mean square error (MSE) between the transmit leakage signal in the input signal and the estimate of the transmit leakage signal in the estimator signal.

20. The wireless device of claim 17, wherein the adaptive filter comprises  
a first multiplier operative to multiply the output signal with an in-phase reference signal and to provide a first in-phase signal,

a first integrator operative to integrate the first in-phase signal and to provide a second in-phase signal,

a second multiplier operative to multiply the second in-phase signal with the in-phase reference signal or a quadrature reference signal and to provide a third in-phase signal, wherein the in-phase and quadrature reference signals are generated from the reference signal,

a third multiplier operative to multiply the output signal with the quadrature reference signal and to provide a first quadrature signal,

a second integrator operative to integrate the first quadrature signal and to provide a second quadrature signal,

a fourth multiplier operative to multiply the second quadrature signal with the in-phase or quadrature reference signal and to provide a third quadrature signal, and wherein the estimator signal is obtained by summing the third in-phase signal and the third quadrature signal, and

a summer operative to subtract the estimator signal from the input signal and to provide the output signal.

21. An apparatus in a wireless full-duplex communication system, comprising:

means for subtracting an estimator signal from an input signal and providing an output signal, the input signal having a transmit leakage signal, the estimator signal having an estimate of the transmit leakage signal, and the output signal having the transmit leakage signal attenuated, wherein the transmit leakage signal corresponds to a portion of a modulated signal being transmitted; and

means for estimating the transmit leakage signal in the input signal based on the output signal and a reference signal and providing the estimator signal, the reference signal having a version of the modulated signal.

22. The apparatus of claim 21, wherein transmit leakage signal in the input signal is estimated based on a least mean squared (LMS) algorithm to minimize a mean square error (MSE) between the transmit leakage signal in the input signal and the estimate of the transmit leakage signal.

23. The apparatus of claim 21, wherein the means for estimating the transmit leakage signal in the input signal comprises

means for multiplying the output signal with an in-phase reference signal to obtain a first in-phase signal,

means for integrating the first in-phase signal to obtain a second in-phase signal,

means for multiplying the second in-phase signal with the in-phase reference signal or a quadrature reference signal to obtain a third in-phase signal, wherein the in-phase and quadrature reference signals are generated from the reference signal,

means for multiplying the output signal with the quadrature reference signal to obtain a first quadrature signal,

means for integrating the first quadrature signal to obtain a second quadrature signal,

means for multiplying the second quadrature signal with the in-phase or quadrature reference signal to obtain a third quadrature signal, and

means for summing the third in-phase signal and the third quadrature signal to obtain the estimator signal.

24. The apparatus of claim 23, wherein the means for estimating the transmit leakage signal in the input signal further comprises

means for filtering the second in-phase signal to obtain a filtered second in-phase signal, and wherein the filtered second in-phase signal is multiplied with the in-phase or quadrature reference signal to obtain the third in-phase signal, and

means for filtering the second quadrature signal to obtain a filtered second quadrature signal, and wherein the filtered second quadrature signal is multiplied with the in-phase or quadrature reference signal to obtain the third quadrature signal.

25. The apparatus of claim 23, further comprising:

means for resetting the second in-phase signal and the second quadrature signal to known values.

26. A method of suppressing transmit leakage signal in a wireless full-duplex communication system, comprising:

subtracting an estimator signal from an input signal to obtain an output signal, the input signal having a transmit leakage signal, the estimator signal having an estimate of the transmit leakage signal, and the output signal having the transmit leakage signal attenuated, wherein the transmit leakage signal is a portion of a modulated signal being transmitted; and

estimating the transmit leakage signal in the input signal based on the output signal and a reference signal having a version of the modulated signal and providing the estimator signal having the estimate of the transmit leakage signal.

27. The method of claim 26, wherein transmit leakage signal in the input signal is estimated based on a least mean squared (LMS) algorithm to minimize a mean square error (MSE) between the transmit leakage signal in the input signal and the estimate of the transmit leakage signal.

28. The method of claim 26, wherein the estimating the transmit leakage signal comprises

    multiplying the output signal with an in-phase reference signal to obtain a first in-phase signal,

    integrating the first in-phase signal to obtain a second in-phase signal,

    multiplying the second in-phase signal with the in-phase reference signal or a quadrature reference signal to obtain a third in-phase signal, wherein the in-phase and quadrature reference signals are generated from the reference signal,

    multiplying the output signal with the quadrature reference signal to obtain a first quadrature signal,

    integrating the first quadrature signal to obtain a second quadrature signal,

    multiplying the second quadrature signal with the in-phase or quadrature reference signal to obtain a third quadrature signal, and

    summing the third in-phase signal and the third quadrature signal to obtain the estimator signal.